SIMULATIONS MODULE

INTRODUCTION

In this module, you'll learn to define several types of simulations, examine the domains in which they are used, and you will explore some of the benefits and challenges typically encountered when applying simulations in the field.

Simulations are powerful tools that are now pervasive throughout every day life—encompassing both military and civilian operations. Every day around the world, simulations help millions of people in thousands of different career fields prepare, train, develop, and apply new skills with increasing precision and accuracy (Defense Modeling and Simulation Office, n.d., Staff Officer Course). Simulations enable people to work more productively together with increased efficiency, improved effectiveness, and reduced risk (National Training Systems Association, n.d.). Simulations are being used daily to save money and time and to protect both the environment and human life.

As the use of simulation technology continues to expand, it becomes increasingly important for M&S end-users to understand the different types of simulation and their appropriate uses.

DEFINITION

In this topic, you will learn the standard definition of the term "simulation," and further explore the difference between models and simulations.

A simulation is a method for implementing a model over a period of time (DoD Directive 5000.59, 1994, P#132, E2.1.16). While models are static by nature, simulations are dynamic. That is, simulations incorporate models to represent change over time. The dynamics of each simulation are as different as the many variables that are part of the simulation.

The roots of simulation go back thousands of years and can be traced back to a longstanding human pursuit of observing objects and behaviors in order to improve understanding and prediction. Throughout history, humans have used various forms of simulation to make advances in a variety of disciplines, including science, education, business, and military defense. From the earliest techniques to simulate combat with wooden swords, simulation has continued to evolve. As knowledge and technology have progressed, the ability for simulations to represent more complex and interconnected situations has likewise increased (Defense Modeling and Simulation Office, n.d., Staff Officer's Course). Simulations are used today in many familiar areas, including weather prediction, ballistics, economic forecasts, manufacturing design, athletic performance, military strategy, and even entertainment.

The difference between models and simulations goes beyond simple dynamics. Models are the basis for simulations. They provide the rules and data for the simulations to run over time. If there were no models, there would be nothing to simulate.

Keeping the model separate from the simulation allows for the model to be modified, updated and more easily validated (Naval Studies Board & National Resource Council, 1997c, Chapter 4).

Spotlight: While models play an important role in supporting simulations, the model must *always* be separable from the simulation.

Let's take a moment to explore a few examples.

- **In the field of Medical Education,** physicians train by conducting surgery inside a simulation utilizing 3-D models of the eye and surgical instruments. If the models are kept separate from the simulation itself, then they could be updated as our understanding of the human eye develops (Peifer, n.d.).
- **Synthetic Environments:** A current M&S trend involves the creation of realistic virtual urban environments. Anticipated *applications* of these models include responding to chemical or biological contamination, conducting urban warfare, providing humanitarian assistance and conducting peacekeeping operations (Clover, n.d.; Krulak, n.d.). Theoretically, if models of urban environments were kept separate from their simulations, then it would be possible to validate and re-use those models for such diverse purposes. However, as you will learn throughout this course, realizing such a goal can be very challenging.

Topic Summary: In this topic, you learned that simulations have a long history of development, and that they are currently used in a wide variety of areas.

You should also have a better understanding of the difference between models and simulations. A model provides the rules and data for simulations to run over time, and is the basis for a simulation; while a simulation is a method for implementing a model over time.

One of the most critical points to remember is that models must always be separable from the simulation. This enables us to update, modify, and validate those models as our needs and--our understanding of the reality we are modeling--change. This makes for more valid and hence more usable simulations.

IMPORTANCE

In this Topic, you will learn about the importance of simulations, and discover how they can increase efficiency, improve effectiveness, and reduce risk (National Training Systems Association, n.d.).

Efficiency

Simulations can increase efficiency in many ways. They can enhance the sharing of information among large and diverse communities of experts by providing manageable representations of complex processes and situations (Defense Modeling and Simulation Office, n.d., M&S Staff Officer Course). This allows for peer review and group collaboration, enabling multiple interpretations and application of simulation data and results.

Simulations are generally more available (Malmin, & Reibling, 1995; National Training Systems Association, n.d.), while *actual* equipment or real-world situations may not always be available or their use may not be feasible.

Simulations can be run faster than actual equipment or real-world situations (Malmin, & Reibling, 1995). For example, when simulated aircraft are "killed," they can be immediately removed from the scenario. Simulations can not only be *reset* quickly, they can also be *accelerated* to provide results faster than real-time (Malmin, & Reibling, 1995).

Simulated events are reproducible (Malmin, & Reibling, (1995); Schutzmeister, 2002). This means that simulations can be repeated with precision. This provides a useful tool for training scenarios that require repetition, both for individuals needing to repeat a simulated experience so they can absorb the information over multiple sessions, as well as for larger groups where all individuals need to be trained with the same scenario.

A simulation can refine training to a specific task (Schutzmeister, 2002). This allows the learner to focus on a given objective without having to engage in ancillary activities that are not central to the specific training objective. Additionally, the learner can repeat finite training actions in a compressed period of time in order to hone specific skills. For example, a fighter pilot can concentrate on dog fighting skills in a simulator without having to take-off, refuel in mid-air, or land. Of course, these skills could be included as part of the simulation if they were deemed critical to the specific task at hand.

Another way that simulations increase efficiency is that they can save money (Department of the Army, Simulation Operations, FA57; National Training Systems Association, n.d.; Schutzmeister, 2002). A simulation does not require the same amount of supplies or resources as its real-world counterpart. For example, using a real aircraft instead of an aircraft simulator would incur fuel, ammunition, and higher repair costs. Cost savings are a significant rationale for modeling and simulation. Sometimes, the cost for accurately and appropriately utilizing M&S may *appear* expensive. However, when compared to the actual costs of trying to capture those same data in the real world, modeling and simulation is almost always the less costly option…especially when the benefits of repeatability, availability, and refinement are taken into consideration (Naval Studies Board & National Resource Council, 1997b, Chapter 2). Let's listen to what Herb Grover has to say about the cost of M&S:

> It has been said by many, in lots of different venues that training in Models and Simulations is far cheaper than having to actually execute war plans using real weapon systems with real airspace…My personal opinion is that Models and Simulations probably ought to be the first choice of

> commanders and staffs who want to practice and facilitate the interaction between the elements of their staff, without having to spend a lot of money to make it happen (Herb Grover, videotaped interview, ITSEC, November 2002, Orlando, FL: Integrity Arts & Technology, Inc.).

Simulations are less intrusive on the environment (National Training Systems Association, n.d , Risk Reduction Section; Schutzmeister, 2002). This means that simulations can allow for effective training and testing without utilizing large tracts of land, sea or air, thereby protecting both the environment and wildlife. Simulations can also be less intrusive to populated areas by generating significantly less noise pollution, air pollution, and other potential contaminants or residual after-effects.

For the military community, simulations are often the only practical and affordable means to improve the training of commanders and their staffs. In other words, a simulation can be used to refine strategy and develop tactics without requiring the use of actual forces in the field (Defense Science Board, 1988).

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Effectiveness

In addition to increasing efficiency, simulations also help to improve effectiveness (National Training Systems Association, n.d.). Many of these improvements in effectiveness are made possible by the increases in efficiency discussed previously.

Using simulations can enhance decision-making capabilities by allowing participants to implement and review the merits of alternative approaches to a specific situation or challenge (Defense Modeling and Simulation Office, n.d., M&S Staff Officer

Course). Being able to observe the differing strengths and weaknesses of various options empowers leadership to make informed and appropriate choices.

Simulations can provide highly flexible and accurate tools to create realistic developmental and operational test scenarios. This not only allows for valuable trial and error feedback during design and development, but also enables similar feedback mechanisms to monitor potential uses prior to implementation. This ability to provide immediate feedback allows for optimizing performance both before distribution and later during application out in the field.

Simulations can also improve the effectiveness of *performance* (National Training Systems Association, n.d.). The supporting examples are as many as they are diverse, from the U.S. Army winning the Canadian Armor Trophy for the first time after starting to train with tank simulators, to the first moon landing, which was described as being "just like the simulator." (National Training Systems Association, n.d.). In fact, a study of flight simulation effectiveness from 1976 to 1989 consistently showed that simulation training combined with aircraft training produced superior pilot performance as opposed to aircraft training alone (Hays, Jacobs, Prince, C., & Salas, 1992).

Simulations can also improve the effectiveness of *training* by providing the learner with well designed cause-and-effect feedback almost immediately, when it is most beneficial (Malmin and Reibling, 1995). This means that the simulation not only engages the student as a means to train, but the student's performance during the simulation is also analyzed and fed back to the student so that performance can be improved.

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Risk reduction

The third important benefit of simulation is *risk reduction*. Simulations can reduce developmental risks by allowing testing prior to large expenditures of time and resources (Gordon, 2001; National Training Systems Association, n.d., Risk Reduction Section). In other words, the risks of using or depleting costly or limited supplies on improper courses of action is lessened. For example, the size of a new truck engine can be determined without having to build several engines of different sizes.

Simulations can *reduce the risk of injury or death* while training for high-risk tasks (National Training Systems, n.d., Risk Reduction Section; Schutzmeister, 2002). For example, simulations can be used for firefighting, high-risk aircraft maneuvers, or dealing with dangerous materials. In fact, simulations “saved literally hundreds of lives”, according to Lt General Glosson, director of air campaign planning during the 1990 and 1991 Gulf War by helping choreograph the thousands of aircraft sorties and other aerial operations thus avoiding mid-air collisions (National Training Systems Association , n.d. Risk Reduction section, Gulf War Analysis Section, 1).

Simulations can be used for training when it is impossible to train on actual equipment. For example, training to land on the Moon was not possible on Earth. However, simulations made it possible for NASA to train both astronauts and ground personnel prior to the actual mission (National Training Systems Association, n.d., Effectiveness Section). By enabling the team to train on Earth, simulations reduced the risk of mission failure, loss of human life and damage to expensive equipment.

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From this discussion of how simulations can *increase efficiency*, *improve effectiveness*, and *reduce risk*, it should be clear that simulations are important tools for today's society. However, it's critical to remember that simulations are just tools—the most important element of M&S is not the technology itself, but how effectively we can apply it.

So, how should we *use* simulations? One approach is to use simulations to size the problem, and determine the amount of resources needed (Michael Macedonia, personal communication, November 14, 2003). Herb Grover has some thoughts about using simulations in this manner….

> Simulations by in large are used to help frame the problem. They can highlight areas that perhaps we haven't addressed in our own planning process. They might identify problems that we didn't think of, perhaps logistics, perhaps munitions not being on a base that needed more high-speed anti-radiation missiles for instance. Often times we find that intelligence staffs don't necessarily address the air defense adequately and perhaps mission plan right through a very dense or defense threat. (Herb Grover video, videotaped interview, ITSEC, December 2002, Orlando, FL: Integrity Arts & Technology, Inc.

This example points out how a simulation, used well, can help us be both more efficient and effective planners.

We can also use simulation to help us make decisions inform our decision-making while conducting a threat analysis. Suppose an opposing force builds a bigger firearm. A decision needs to be made regarding how to counteract this new threat. One option might be to build a larger firearm to counteract the adversary's weapon. However, there might be other alternatives, like building tanks with thicker armor or developing a new type of ammunition for existing weapons (Dell Lunceford, personal communication, June 18, 2002). This example illustrates how simulation can provide us with an understanding for alternative options. This analysis of alternatives, or AoA, can save time and money.

If the choice is to build a new firearm, other simulations can help design that new weapon, develop prototypes of it, test it inside the simulation, train people how to operate the weapon, and develop tactics and doctrine for how to use it.

Spotlight: Simulations *cannot* make decisions for you, but they do provide valuable data to help *you* make an informed choice.

The final decision for how data from a simulation will be used is always up to the people using that simulation and they need to be aware that human biases, differing experiences, and perspectives will influence their decisions. Understanding that simulations are only *tools*, and ones that can be misused just like other tools, is an important consideration when applying M&S.

Topic Summary:

This topic explored three primary reasons why simulations are important: they can be used to increase efficiency, improve effectiveness and reduce risk. Simulations can increase efficiency by reducing the cost associated with supplies, resources and time, and by being less intrusive on both the environment and populated areas. Simulations can improve effectiveness by enhancing leadership and decision-making, product development, and training effectiveness. Simulations can reduce the risk of human injury or death, reduce the wasting of money or resources, reduce mission failures, and reduce equipment damage associated with training for dangerous tasks or when the real equipment is not available.

In other words, simulations are important because they provide us with the data and the tools we need to make more informed decisions earlier on, before too much time and money is spent, the environment is impacted, and lives are lost or adversely affected.

However, since they are just tools, simulations can only reach their potential if we implement them appropriately and responsibly.

TYPES

In this Topic, you'll learn about three types of simulations, explore the benefits and drawbacks of those simulation types, and discover the shades of gray involved in categorizing simulations.

There are three types of simulations: live, virtual and constructive (DoD Directive 5000.59, 1994, #110). However, as important as knowing these three different types of simulations, is the understanding that finding a simulation that is truly just one of these types is more the exception than the rule.

> **DRILL DOWN,** *Simulation Types*
> Schutzmeister, S. (2002; February). *Models and simulation topic/system summaries*. Unpublished conference manuscript. Synthetic Training Environment Periodic Review (STEPR), pp. 2-3.

Most simulations are a combination or hybrid of the separate live, virtual, or constructive components. This is a prime example of the "shades of gray" that are found throughout the field of modeling and simulation. In fact, the M&S glossary released by the Department of Defense (1995, #110) notes, "The categorization of simulation into live, virtual, and constructive is problematic, because there is no clear division between these categories." An awareness of the characteristics, strengths, and limitations of each simulation type, will help you understand how they can be combined and what benefits can be gained from their use.

Spotlight: Although one of the categories of simulations is called "live," it is important to remember that all three types of simulations involve live people interacting with the simulation in some manner.

A *live* simulation is one that involves real people operating real systems (DoD Directive 5000.59, 1994, #110). The best way to illustrate this is to think of what is commonly referred to as "practice", whether it be a warm- up swing with a golf club, target practice, or full-scale military maneuvers on large ranges like the National Training Center in California. A good example of live simulation developed for military training is the Multiple Integrated Laser Engagement Simulation, or MILES. This simulation has become well known in the civilian world as "laser tag" (MILES 2000).

Using a *live* simulation provides certain unique benefits. For example, individuals or groups of people can experience the use of real equipment within a similar area of operation in a realistic environment (Schutzmeister, 2002). Participants can actually experience operating their equipment in the bitter cold of winter or the searing desert heat. Live simulation, also introduces real stressors, such as "live" enemy forces that prosecute with motivation and consequences. The result is that trainees experience what a "live" enemy might do rather than guessing about these actions.

However, live simulations also present certain *limitations*. These include the inability to fully replicate the actual activity. For example, not all weapons simulations can be employed in a live environment. Specifically, the MILES system will not work in fog or rain. Another limitation is the potential for expending large amounts of resources in order to support a live simulation. Consider the cost of land at a large range like the National Training Center. Other limitations include possible safety hazards, and the risk of equipment damage.

A *virtual* simulation is one involving real people operating simulated systems (DoD Directive 5000.59, 1994, #110). Examples of virtual simulations include flight simulators, driving simulators, and other simulators using computer-generated visualizations. All virtual simulations have a live participant with a visual display that has a representation of the environment. This live participant is also known as a "human-in-the-loop."

Be careful, people often confuse the terms "virtual simulation" and "virtual reality." Virtual reality is a subset of virtual simulation in which the participant is isolated from stimuli outside the simulation. In virtual reality, the participant operates while immersed in the virtual simulation through the use of specialized equipment like head-mounted displays or 360 degree display walls. But there are other types of virtual simulations that use computer screens or other types of displays, which do *not* fully immerse the user (Navy Modeling and Simulation Management Office, n.d.).

Spotlight: Virtual reality is a subset of virtual simulation.

The *benefits* of virtual simulations include the ability to provide various degrees of equipment realism. This variable range of presentation is called fidelity and will be discussed in detail later in the course. Other benefits include the ability to repeat or redo a scenario multiple times and under different conditions. Virtual simulations also provide the opportunity to practice decision and communication skills in various repeatable scenarios, as well as performing high risk or expensive tasks. Another benefit is that virtual simulations can often save money over other types of simulations. For example, a virtual simulation can allow for a change of weather conditions, time of day or other circumstances quickly and easily, rather than having to delay or adjust according to real world factors, as in live simulation.

Virtual simulations do have certain *limitations*. The primary limitation is that virtual simulations cannot fully replicate real world conditions. Because of this, virtual simulations cannot subject equipment to developmental testing as extensively as live simulations can. Let's hear what Ron Wolff has to say about the use of simulations for operational testing:

> One thing that we certainly cannot do in the virtual world is subject weapon systems to the type of environment effects that they would want to test those weapons to such as water, mud, freezing rain, dropping the weapon, the rounds flying out of the weapon, the cycle rate of the weapon. All of these types of things would have to be done, and continue to be in operational testing. It's the other types of things that are not so much stress related that we can do in the virtual world. (Ron Wolff, videotaped interview, December 2002, ITSEC, Orlando, FL: Integrity Arts & Technology, Inc.)

Virtual simulations are also limited by their inability to teach "field craft," that is, operating under real world situations such as working in mud or salt spray (William Blackledge, personal communication, November 7, 2002). Another challenge in using virtual simulations is that users may distrust them simply because they are *perceived* as being less realistic than actual equipment—even when the simulations contains sufficient detail for the current task at hand.

Constructive simulation is the third type of simulation to be discussed. Constructive simulation involves simulated people operating simulated systems (DoD Directive 5000.59, 1994, #110). A constructive simulation, may include combinations of computer

programs, computer-mediated war games, and role-playing simulations. An example of constructive simulation is the Air Warfare Simulation (or AWSIM) (National Simulation Center, 2001; Air Force Agency for Modeling and Simulation, 2003)--used to train senior commanders and their battle staffs (Schutzmeister, 2002). The red and blue images represent simulated opposing and friendly forces operating in a simulated environment.

In some constructive simulations, people may stimulate, or inject signals into an actual piece of equipment. This enables the equipment to behave as it would if real signals were being detected (DoD Directive 5000.59, 1994, P#134, 110). However, computer programs--or the rules of the simulation--determine the outcomes. For example, a user might instruct a simulated troop to attack an opposing target, but the outcome of that attack would be determined by the rules of the constructive simulation.

Constructive simulation can also be *embedded* in a large field exercise. Within this *live* simulation, radio reports are received indicating events happening elsewhere that provides participants with the information they need to make decisions (William Blackledge, personal communication, November 7, 2002). If these events did not *really* take place, but were fabricated by someone to *stimulate* the live simulation, then we can categorize this fleet exercise as one that utilizes *constructive* simulation.

The *benefits* of constructive simulations include allowing one to make measurements, generate statistics and perform analysis, and run faster than real time. This is true, to some extent, for all types of simulations, but it is a primary focus of constructive simulations.

Constructive simulations give users the ability to analyze concepts, develop strategies, predict possible outcomes, and aggregate information at a higher level such as representing a unit of troops as a single icon on a computer display. This means that by using constructive simulation to generate appropriate stimulus, observations can be made about the larger entity or organizations that are responding to that stimulus within a larger simulation. This enables constructive simulations to provide capabilities for training *larger* and *broader* audiences, such as battalions or battle groups and also the command staffs that oversee them.

Constructive simulations also have several limitations. Since the stimulated data for all friendly and enemy units is not real, there is no actual, live enemy. All friendly units and enemy units are simulated and may not behave realistically. Also, many constructive simulations use a large number of established, legacy computer systems, which often present challenges when trying to connect with other simulators. Legacy refers to a simulator that was built in the past, but is still being utilized today. This is opposed to a next generation simulator which is one being built now, but that will be *used* in the near future.

Topic Summary:

In this topic, we introduced three types of simulations—live, virtual, and constructive.

A live simulation involves real people operating real systems. A virtual simulation involves real people operating simulated systems. Virtual reality is a sub-set of virtual simulation in which specialized equipment immerses the user into a simulated environment. And constructive simulation involves simulated people operating simulated systems.

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HOW ARE SIMULATIONS USED?

In this topic, you will examine several domains in which simulations are being used, explore the interconnectedness between those domains, and you will examine the critical role that a simulation's purpose plays in determining its appropriate use.

Much like models, simulations can be used for many purposes. However, also like models, any given simulation is intended to support *only* the specific purpose for which it was created. For example, using the same tank simulator for gunnery training and driver training may not be effective. While there are many existing simulations, it's important to understand that they were created for *specific* purposes and no matter how close or approximate to the needs of another task, an existing simulation may not be able to serve a new purpose (Amico, Bruzzone, & Guha, 2001, p. 4).

Simulations are tools that can be used in three main areas of concentration or Functional Domains: training, analysis, and acquisition (Defense Modeling and Simulation Office, n.d., M&S Staff Officer Course; Defense Modeling and Simulation, n.d., M101; Navy Modeling and Simulation Management Office, n.d.).

These three functional domains can be illustrated by once again building upon the graphic model that was introduced earlier. This diagram depicts the characteristics of things that can be modeled as well as possible levels of aggregation. To get a better understanding of how M&S is applied, this diagram is expanded into a three dimensional cube (Adapted from: Amico, Bruzzone, & Guha,2001; Department of Defense.1995, 2-2; Naval Studies Board & National Resource Council, 1997a, Chapter 1, p. 2). Now, the three functional domains of simulation are along the sides of the cube. This implies how a specific type of model can be used in conjunction with a specific type of simulation.

To demonstrate, think back to the ejection seat example from the Models module. The ejection seat, modeled at the component level of aggregation, can be used in a simulation for training – say, technicians learning to repair the ejection system. That same ejection seat model could also be used in a simulation for analysis – say, determining the threshold for failure of the seat under extreme G-forces. Finally, the ejection seat model might be used in an acquisition simulation – say, calculating the total amount of padded cushion needed to be requisitioned in order to fulfill a large order for new airplanes.

Each functional domain has several aspects to it that provide a greater level of detail for determining the use of a simulation. In the *training* domain, simulations can train specific tasks at the *individual* level: procedural tasks – fixing the fuel line on an engine; cognitive thinking – determining if a small boat crossing the heading of another ship presents a danger; and motor skills – operating the stick and rudder of an airplane.

Simulations can also train *collective* tasks, or those that are accomplished by a team or group. For example, staff decision making (like choosing alternative courses of action); and training of crew skills (like flight crew communication or fire fighting skills for damage control) involve teams of people training together. Let's listen to Gary Fraas discuss the use of simulations to support team interaction:

> That's where we're seeing the power of simulation really pay dividends. The team interaction is so important, and using the networking and distributed simulation we are able to tie more and more systems together and composing larger and larger teams." (Gary Fraas videotaped interview, ITSEC, December 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

In the *analysis* domain, simulations help decision makers rapidly answer "what if" questions, identify constraints, test the results of failure, and prioritize issues in order to focus on the most important. For example, military planners might use a simulation to help analyze alternative tactics such as whether to take a bridge or ford the river at another location.

In the *acquisition* domain, simulations can be used to enhance many aspects of the acquisition process. For example, they can aid in the early feasibility designs of new systems by narrowing the scope of possible design approaches. They can also augment developmental testing of selected design approaches by providing tools to try out alternative concepts. Other uses include determining logistics requirements of system production (for example, how many people need to work on an assembly line), and representing external factors that will affect the implementation of new systems (for example, determining how much fuel is needed for a new truck). Ron Wolff has some thoughts on how simulations can be used for developmental testing:

> If we bring in a weapons system into the test bed we'll analyze that data to get a better understanding of how the weapons perform in a situation that we're testing. The idea is we can do all of those design issues and tradeoffs upfront before we actually go off and build the hardware and put a lot of money into the development of a system that we still haven't really tried or tested. (Ron Wolff, videotaped interview, ITSEC, December 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

Experimentation is sometimes regarded as another functional domain (Defense Modeling and Simulation Office, n.d., Staff Officer Course). Experimentation is not like an experiment in chemistry class where the outcome is known and certain if properly executed (Gourley, 2002). "Experimentation," as the term is applied in M&S, is often used to examine new systems or new ways of using existing systems.

This is an example of how M&S is continuing to evolve and redefine itself as it matures as a field of study.

Modeling and simulation tools also support a major new initiative within the Department of Defense known as Simulation-Based Acquisition, or SBA. As discussed in the history model, Simulation-based Acquisition uses M&S technologies and techniques to determine equipment needs, streamline their production, and integrate them in less time and at lower cost than traditional means (Defense Modeling and Simulation, n.d., M&S Staff Officer Course; Ivanetich, 1997; Wolff, 1999).

The concept behind SBA is that M&S tools can be utilized throughout the entire procurement system lifecycle–from requisition to implementation. Simulation-based Acquisition also recognizes that important contributions from the other functional domains – training and analysis – are necessary to complete this iterative and collaborative process. The U.S. Army highlights these interconnections between the functional domains by calling their program for simulation-based acquisition SMART, or Simulation and Modeling for Acquisition, Requirements, and Training (SMART 2001, 2002; US Army Visual Information Center, 2002).

The idea is to share the data for models and simulations among the acquisition, requirements, training, and testing communities during the development process of new systems. Doing so makes M&S data available to everyone and enables teams to optimize the future system before it gets into production. The goal is to reduce ownership cost, shorten time required to field new systems, and to help ensure high quality and military effectiveness.

Topic Summary:

In this topic, you learned more about the critical role *purpose* plays in simulations. That is, since any given simulation is intended to support only the goal for which it was designed, it may not be able to serve a new purpose. And you explored how simulations are supporting work in three functional domains: training, analysis and acquisition. Lastly, this topic also introduced examples of how the field of M&S is continuing to evolve and re-define itself. For example, experimentation is now being considered by many as a fourth functional domain of simulation usage. Additionally, two new initiatives, SBA and SMART, are striving to increase the power of M&S by interconnecting activities across a variety of application areas.

NETWORKED SIMULATIONS

In this topic, you will explore some of the benefits of connecting simulations, examine both technical and human issues regarding the development and use of networked simulations, and you will learn to define several core concepts within this area of M&S.

Many simulations exist individually. However, the M&S community has discovered that when individual simulations are connected together, their functionality increases to support not only the skills of individuals, but also the performance of teams or larger groups. This has led to the development of *networked* simulations, or simulations that are connected together to work in unison sharing the same models and simulated environments (Defense Modeling and Simulation, n.d., M&S Staff Officer Course). These networked simulators may be many miles away from each other, yet can be used as if they were in the same location. The use of networked simulations to conduct combined, collective, or joint exercises is becoming increasingly important.

If the goal is to train as realistically as possible, then it is important to recognize that most training activities are not based on individual, isolated performances but are group actions or individual skills rehearsed as part of a group activity. Therefore, to maximize the effectiveness of simulated training, networked simulations are preferable to isolated, individual simulations as a means to increase the functionality of the overall training simulation by including more participants and different levels of aggregation.

A future goal for M&S is to bring individual and team-based training to deployed war fighters. Doing so, would reduce the costs and inconvenience associated with traveling to distant training sites. Let's listen to Gary Fraas discuss the goal of using networked simulations to bring training to deployed war fighters:

> But what we're trying to do is migrate training from the shore-based facility and actually get to a case where we can deploy it, to the war fighter. Bring the training to the war fighter, rather than having bring them to the training site. So, you're going to continue to see a lot of that happening. You are going to continue to see more and more applications that are done in a distance learning environment, through the Internet or some other kind of a networking scheme. (Gary Fraas, videotaped interview, December 2002, ITSEC, Orlando, FL: Integrity Arts & Technology, Inc.)

To accomplish this, the simulations must be able to communicate with one another. Not just in terms of translatable programming languages, but also in the context of what each of them are representing. For instance, trees in one simulation need to be recognized as trees in another one, not as buildings.

The goal of simulators communicating with one another is also referred to as interoperability, or the ability for different simulators to work together (DoD Directive 5000.59, 1994, P# 115). This drive toward future progress for networked simulation has led to the development of High Level Architecture, or HLA, as the current established standard for interoperability within the U.S. Department of Defense (DoD Directive 5000.59, 1994, P# 100; Defense Modeling and Simulation Office, n.d., HLA). Interoperability standards, like HLA, help reach the goal of leveraging the existing base of legacy simulators and simulation applications. It also promotes the development of future simulators and simulations that are interoperable. Individual simulators need to be able to connect with other simulators and participate in larger networked simulations if the M&S industry is to continue its evolution. Let's hear how Gary Fraas describes interoperability:

> …interoperability is the notion that different simulations should be able to share information across a network. That network may be located simply in a single site in a single room, or it may be distributed around the world using a high-speed telecommunications network. So, interoperability is the ability for simulations to provide and exchange information, and more importantly understand the information that is being passed." (Gary Fraas videotaped interview, ITSEC, December 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

As mentioned in the History module, SIMNET is widely regarded as being the first successful networked simulation. SIMNET enabled individual tank simulators located at various Army locations across the country to remotely participate in collective training exercises in real time. This use of a shared virtual simulation demonstrated the potential for networked simulations and paved the way for future efforts to enhance the capabilities of networked simulations.

Another example of networked simulation was the Multi-Service Distributed Training Test Bed Program, or MDT-2, that took place in the mid-1990's (Institute for Defense Analyses, & US Army Research Institute for the Behavioral and Social Sciences, n.d.). MDT-2 involved the Air Force, Army, Navy, and Marines and was truly a joint program whereby several legacy systems around the country were networked together to create an opportunity for active duty service members to practice Close Air Support. These different simulators allowed for fighter jets, tanks, and laser designators to all engage within the same simulation. All participants were able to interact with the same terrain at the same time via the Internet. There were several challenges faced in the MDT-2 program. For example, early versions of the simulation had planes flying through mountains, and tanks that traveled above the ground. But these issues were addressed by the researchers.

> **DRILL DOWN**, *MDT-2 Results*: MDT-2 enabled the four services of the Armed Forces to interact on the same battlefield environment and participate in a joint exercise practicing a close air support mission. Previously, each service had practiced their own portion of the mission in isolation. The first time they would work together would be on a live range, at great cost and expenditure of resources. However, by using the MDT-2 network simulation, all four services were able to work out some of the inter-service differences and logistical issues within a simulated environment before making the large-scale commitment to attend the live range. Once those issues were identified and resolved, the four services returned to the live range and found that the networked simulation training had greatly increased their efficiency once on the live range. The result was a much more effective expenditure of manpower, equipment and resources during the live simulation due to the information provided by the networked simulation prior to the live event (Institute for Defense Analyses, & US Army Research Institute for the Behavioral and Social Sciences, n.d.).

> **DRILL DOWN**, *MDT-2 Communication*:
> … by doing this in a simulated environment we were able to work out some of the inter-service differences in a simulated environment before they actually went to a live range and improve their proficiency over the course of that week So, there are a lot of communication problems both within each of the services, and across the different services. Using Modeling and Simulation like we did in the MDT-2 Program allowed us to uncover and discover some of those communication problems in a simulated training environment before we actually went out and did this for real (Dan Dwyer, videotaped interview, ITSEC, November 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

For the most part, the discussion of networked simulation has centered on technological issues. However, human performance and human performance measurement and feedback are also important considerations, especially in the training domain. To successfully include human performance in a simulation, there are several factors that need to be identified. These include clearly defining the training objectives, creating scenarios designed to meet those objectives, providing opportunities for trainees to practice and demonstrate desired behaviors, developing methods to measure performance, and determining techniques to provide feedback to reinforce correct behaviors and remediate incorrect behaviors – for example, After Action Reviews.

In MDT-2, it was not enough to determine results based on traditional outcome measures, such as whether a bomb hit its target on time. A significant amount of development effort was spent up front determining new means of measurement to gauge human performance and determine actions for how to improve execution of the training objectives during the course of the exercise.

Topic Summary:

Let's review several of the terms that were introduced in this Topic. Networked simulations refers to simulations that are connected together to work in unison sharing the same models and simulated environments. Interoperability is the ability for different simulators to work together. And High Level Architecture (or HLA) is the current established standard for interoperability within the U.S. Department of Defense.

This topic also discussed several benefits of networked simulations. For example, networked simulations can maximize the effectiveness of simulated team training and they can increase efficiency by reducing the need for participants to travel to various training sites. To accomplish this and other related goals, however, the field of M&S must first solve several challenges that it is currently facing. For example, we need to build simulations that can communicate effectively with each other and we need to develop new types of human performance measurement for these new learning environments.

CHALLENGES

In this Topic, you will explore some of the challenges in developing and implementing simulations. And you will hear from M&S practitioners as they share their reflections and practical guidelines.

Simulations create several challenges, both for the developer and the end-user. There is an important process that should be followed to make sure any given model or simulation is valid for its intended purpose. One challenge is that the user may not *trust* in the model and the simulation if his or her needs were not properly validated throughout the development process. This ongoing validation process is critical to the success of any M&S project. Validation is a great concern to the M&S community, since a vicious cycle of diminishing confidence can spiral out-of-control when a simulation is not properly validated. If some end-users are aware that certain assumptions are incorrect or invalid in the creation of a simulation, then the entire outcome of that simulation is jeopardized. Herb Grover has some thoughts on this issue…

> It has been my experience particularly in training exercises that some commanders come into that training environment anticipating that the simulation is not going to accurately portray their war plan. So, very often once the engagement is conducted in the event, in the exercise, in the computer that whatever the consequence of that activity was they are likely to disallow and suggest that wasn't how their weapon system would have performed. Or if a real operator had been in that weapon system, that is not what they would have done. (Herb Grover, videotaped interview, ITSEC, December 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

So, a lack of faith in the simulation or distrust of the data it produces impacts how people will use or misuse that information.

There are discernable steps in the iterative process of developing models and simulation that will be covered in more detail later in this course. The most important lesson of this process is realizing that no step can be skipped without running the potential for invalidating the results and developing mistrust of the simulation by the end-user

Another challenge to simulations is maintaining an unbiased perspective regarding the use of existing simulations that may be available for other projects. Sometimes, people who spend significant time in the development, creation, or use of a simulation *believe* that their simulation is appropriate for additional purposes. While this is a suitable goal and can provide cost effectiveness by reusing simulations, it is often the wrong means to the right end.

Within the M&S community, this is often referred to as "falling in love with your simulation." Limiting personal involvement and keeping an appropriate professional separation from the product or accomplishments of an M&S project is important in maintaining a neutral and unbiased perspective, not only for the validation process of that project but also for any additional opportunities for re-use or re-purposing. Again, the validity of the simulation and the accuracy of the data it generates in support of the specific purpose for which it was intended are more important than the potential for re-use. Michael Macedonia has some words of wisdom on this subject…

> In a sense…what people are trying to do with simulation is to find the truth. The truth about the battle field, the truth about the weather, the truth about the road traffic in your area. … You have to understand that, again, it is only an abstraction. It is not the truth. You're only trying to represent the truth. And keep your mind open to other people's ideas, and to other ways of doing simulation… And also realize that there is no perfect simulation. There is no single truth embodied in a piece of software. Don't fall in love with your simulation, keep an open mind…(Michael Macedonia, videotaped interview, ITSEC, December 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

This point leads to the larger issue of re-use and re-purposing of simulations in general. The ability to recycle simulations, especially legacy applications, is a tantalizing opportunity. However, it is crucial to make sure that the re-use of the simulation is validated with as much care as the original use. The potential for re-use is one of the major reasons why the model always needs to be separable from the simulation.

The overall challenge then is to choose or develop models and simulations that are appropriate for the task at hand. If existing models and simulations are to be utilized or adapted, then users must exercise diligence in validating them for their *new* purpose. Users have to be certain they haven't simply latched onto a simulation that they feel comfortable with or have access to, and they have to ensure that their end-users trust the M&S system as it is being implemented.

Networking simulations together also presents unique challenges. The greatest of these is the issue of interoperability, or enabling different types of simulations to interact with each other and to connect to other simulations at different levels of aggregation. This is especially challenging when trying to incorporate legacy applications or simulators. This is the reason that so much emphasis is being placed on standards like High-Level Architecture.

Another challenge for simulations is that it is not possible to simulate every characteristic of reality. Tradeoff decisions must be made to select the appropriate characteristics that meet the needs of the user under the constraints of available resources and technological capabilities (The Project Manager Combined Arms Tactical Trainer, n.d.; Ivanetich, 1997.; Wolff, 1999, p. 8). The next module, Fidelity, will discuss tradeoff issues in more depth.

Finally, another challenge that simulations face is the common misconception of what *is* possible versus what *has actually been achieved.* Within the M&S community this is sometimes referred to as "Hollywood vs. reality" or hype versus fact. Many times, the optimism and enthusiasm for a project breeds statements of a simulation's potential that sound more like accomplishments than expectations. Just as a movie audience is led to believe that what they see on the screen is real, marketing hype can make a simulation seem to be more than it really is. End-users may form unrealistic expectations about the characteristics and capabilities of the simulations based upon what they see or hear. Therefore, it is important to keep an accurate assessment of what a simulation does and what it enables. The bottom line? Be as precise with pronouncements about a simulation as with the data and assumptions that support it.

Topic Summary:

Let's review some of the challenges and practical guidelines that were covered in this topic. The primary goal is to choose or develop simulations that are appropriate for the task at hand. While this sounds easy, it can be a difficult task to achieve. Several guidelines you should remember are:

- Maintain an unbiased perspective
- Don't fall in love with your model
- Pursue ongoing validation
- Do not skip any step in the M&S development process
- Make certain that the simulation is validated against any potential re-use.

Additionally, clearly define what the simulation can and should do—rather than what people *want, hope or believe* it should do. That is, manage the end-user's expectations by keeping an accurate assessment of what a simulation can and cannot do. And rather than trying to simulate every aspect of reality, select only the appropriate characteristics that meet the end-users' needs, conserve resources, and that are technologically feasible.

SIMULATIONS MODULE SUMMARY

This topic reviews the major concepts introduced in the Simulations Module. A simulation is a method for implementing a model over a period of time. While a model is the basis for a simulation, it must always be kept separable from the simulation. Simulations are powerful tools that have proven their importance by allowing people in a wide variety of fields to increase efficiency, improve effectiveness, and reduce risk. However, it's critical to remember that simulations are just tools and as such they *cannot* make decisions for you. What they can do is provide valuable data to help you make a more informed choice.

There are three main types of simulations: live, virtual and constructive. Virtual reality is a subset of virtual simulation. However, when categorizing simulations, remember that all four of these simulation types involve live people interacting with the simulation in some manner, and that most simulations are hybrids of these terms.

Simulations are generally used in four functional domains: training, analysis, acquisition and experimentation. Currently, there is a trend to interconnect simulation usage across these and other functional domains. And while simulations can be used for many purposes within these domains, any existing simulation is intended to support only the purpose for which it was designed. It may or may not be able to serve a new purpose.

Networking simulations can maximize the effectiveness of simulated team training and increase efficiency by eliminating the need for participants to travel to training centers. In order to realize these goals, however, the field of M&S has to surmount current challenges in interoperability and in human performance measurement.

And lastly, this module suggested two primary guidelines for working with simulations: Choose or develop simulations that are appropriate for the task at hand and clearly define what the simulation can and should do in order to fill that unique need.